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Original communication

Sex identification from fingertip features in Egyptian population

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ABSTRACT

Identification of an individual plays a vital part of any medico-legal investigation. Fingerprints are considered to be one of the most reliable methods of identification. The present study was conducted on 752 healthy adult Egyptian subjects (380 males and 372 females) with age ranged from 20 to 30 years. Consents were obtained from all participants and their 10 digits were photographed to determine the sexual dimorphism by some fingertip features (ridge count, square area, finger breadth and finally ridge density) in Egyptians. Statistical analysis was made using a multivariate logistic regression variation analyses. Results showed that females tend to have statistically significant shorter (narrower) finger breadth (right: male $>$ 9.54 $\geq$ female, left: male $>$ 9.38 $\geq$ female), smaller square area (right: male $\geq$ 16.1 $>$ female, left: male $>$ 15.1 $\geq$ female), more ridge count (right: female $>$ 21.0 $\geq$ male, left: female $>$ 21.2 $\geq$ male), and higher ridge density (right: female $>$1.35 $\geq$ male, left: female $>$ 1.5 $\geq$ male) when compared with males. The ridge density of the left hand was the most single accurate parameter in correct sex determination. The best classification accuracy of 82% was generated upon combining ridge count, square area and ridge density. It was concluded that fingertip features of Egyptians can be used by medico-legal experts for accurate sex identification.

1. Introduction

Determination of individuality is one of the prime issues in forensic practice. Among the number of parameters available for establishing the identity of an individual, fingerprints are extensively used in providing an evidence regarding identity.[1]

The ridge patterns are formed in the human fetus before birth and remain largely unchanged throughout a person's life and even after death until they are lost through decomposition. It is possible to identify not only criminals but also victims of amnesia and unidentified corpses when records of prints are available. If the sex of the individual is established with certainty, the burden of the investigating officer would be reduced by half.[2]

No two fingerprints have ever been found to be identical. Identical twins originating from one fertilized egg are arguably the most alike of any beings on earth. They share the same DNA profile because they began existence as one entity.[3] Despite many well developed fingerprint matching techniques and a wide range of biometric applications, a reliable fingerprint based sex determination method does not seem to be available.[4]

Different fingertip parameters were used to detect sexual dimorphism in different populations. Ridge density has been shown to be sexually dimorphic in Spanish Caucasians,[1] Indians,[2] Southern Indians,[5] Caucasian and African Americans,[6] Chinese and Malaysian people.[7] Esperanza et al.,[8] used minutiae in sex determination of Spanish population. Recently, Nithin et al.[9] applied ridge count in sex determination of South Indian population. To best of our knowledge using fingertip parameters for accurate sex determination among Egyptians was not achieved. So, the present research was designed to study the sex difference using multiple fingertip features (finger breadth, square area, ridge count and density) within an adult Egyptian population.

2. Subjects & methods

Seven hundred and fifty two healthy adult Egyptian subjects (380 males and 372 females) aged between 20 and 30 years were randomly chosen. This age was chosen to ensure fixed ridge width

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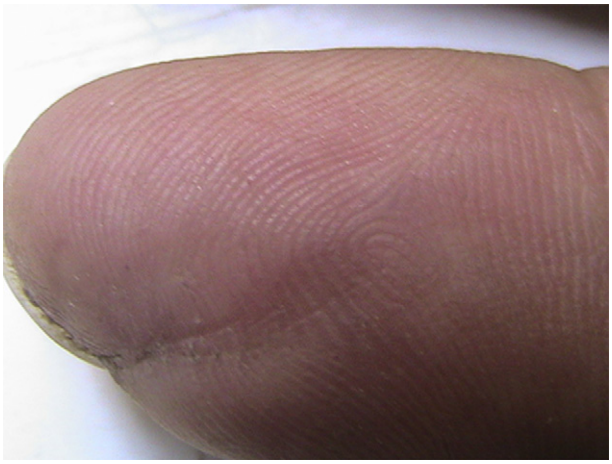

Fig. 1. Diagram showing a finger with scar (exclusion criteria).

as ridge width varies according to age.[10] They were Egyptian students and officials in Faculty of Medicine, Minia University. Subjects with any evidence of disease or injury of the fingertips that were likely to alter the fingerprint pattern (leprosy, scars or laceration…etc.) were excluded (Fig. 1). The purpose of the study was explained and the participants' informed verbal consents were obtained for participation. Subjects were asked to wash and dry their hands to remove any dirt and grease. Every subject was asked to keep his/her arm relaxed.

Fingertip images were captured for the 10 fingers of every participant using a digital camera {Canon (G5) ZR 850-digital video camcorder-2.6–91 mm 1:2.0, 1000× Mega-pixels, video product 2009, Japan}. The camera was fixed on a holder so the distance of capturing was fixed. A code number from 1L to 5L and from 1R to 5R was given to each finger starting from little finger to thumb of left hand and right hand respectively. Photos were transferred to a computer. Images were resized to 10 × 15 cm then printed.

The following steps were carried out for each photo: the finger was longitudinally bisected by a symmetrical axis. Then, a transverse line (line segment of interest) represents finger size (breadth) was drawn perpendicular to the symmetrical axis passing through the core point which is the topmost point of the innermost curving

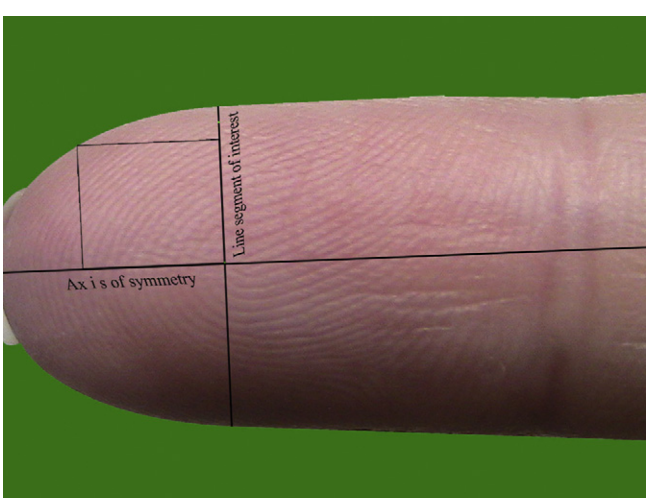

Fig. 2. Diagram showing the selection of the area of interest in left hand of female person (25 years old).

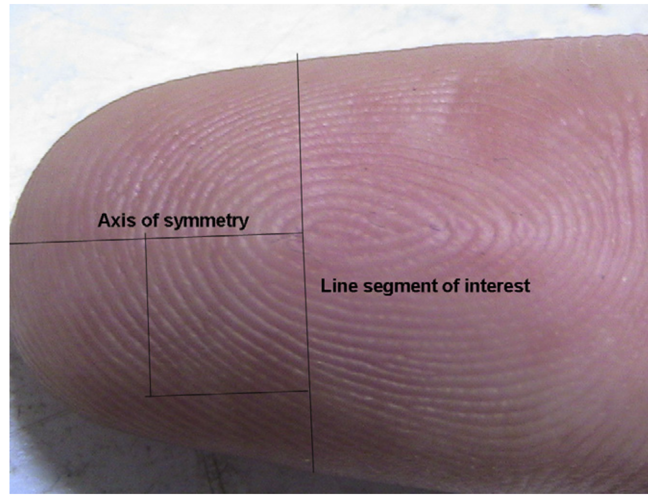

Fig. 3. Diagram showing the selection of the area of interest of in right hand of male person (22 years old).

ridge. Then 10% from both ends of the line segment of interest was extracted as in such regions, the finger surface often varies making counting ridges very difficult. Finally, a square was drawn on the outer radial side of the finger with its side length equal to half of the remaining line segment of interest (Figs. 2 and 3).

For every finger, four measurements were taken: finger breadth, ridge count, square area and finally ridge density (number of ridges in the given square). After Acree,[6] ridge count was carried out diagonally starting from one corner of the square to the opposite corner. The mean values were calculated for the left and right sides separately and then for the two hands; this new value represented the total number of ridges for the individual. The square area was recorded by multiplying the side length of the selected square by itself. Similarly, the mean ridge density for each finger was calculated by dividing its finger ridge count over its square area then the mean for all 10 fingers was estimated for each individual. Differences in the selected fingertip features (finger breadth, square area, ridge count and density) between both sexes were statistically analyzed using SPSS (Statistical Programme for Social Sciences, version 10.0). A multivariate logistic regression variation analysis was done to determine the sex difference of the selected fingertip features for right, left hands and for the mean of all 10 fingers.

3. Results

Results demonstrated that the ridge count features of left hand and the total number of ridge count of both hands yield statistically significant ($t = 3.706$, $p = 0.000$) difference between males and females. Males tend to have lesser number of ridge count (20.500 ± 1.974) compared to females (21.364 ± 2.652) (Table 1).

Both of square areas and ridge densities as well as finger breadth of the two tested hands (total) showed significant sexual dimorphism. Males tend to have statistically significant higher square area ($t = 9.666$, $p < 0.000$), broader finger breadth ($t = 8.517$, $p < 0.000$) and lower ridge density ($t = 9.587$, $p < 0.000$) when compared with females (Tables 2–4).

Comparing results of the individualized (single) tested parameter; finger breadth feature gave the highest result of accuracy in correct sex matching {72.3%}, followed by square area {71.3%}, then ridge density {66.0%} and finally ridge count {62.8%} (Tables 1–4).

A multivariate logistic regression model was used to estimate sex using the ridge count, square area, density and finger breadth of all fingers from both hands. Sex was determined as the dependent

Table 1
Mean, standard deviation, *P*-value and accuracy % of ridge count of studied subjects.

Rridge count	Sex				*t*	*P*-value	Accuracy %		Total accuracy %
	Male		Female						
	Mean	S.D	Mean	S.D			M	F	
Fingers of left hand	20.154	2.150	21.427	3.371	4.416	0.000	74.0%	52.3%	63.8%
Fingers of right hand	20.863	2.344	21.298	2.431	1.763	0.079	76.0%	31.8%	55.3%
Total ridge count	20.500	1.974	21.364	2.652	3.706	0.000	74.0%	50.0%	62.8%

S.D: Standard deviation.

Table 2
Mean, standard deviation, *P*-value and accuracy % of square area (cm^2) of studied subjects.

Square area	Sex				*t*	*P*-value	Accuracy %		Total accuracy %
	Male		Female						
	Mean	S.D	Mean	S.D			M	F	
Fingers of left hand	16.224	2.301	13.601	3.648	8.426	0.000	76.0%	70.5%	73.4%
Fingers of right hand	17.180	3.148	14.130	3.70	8.639	0.000	80.0%	63.6%	72.3%
Total square area	16.7948	2.548	13.868	3.312	9.666	0.000	76.0%	65.9%	71.3%

S.D: Standard deviation.

variable (Table 5). The ridge density of the left hand was the most single accurate parameter in correct sex determination (male 84% and female 70.5%). The cutoff point and the classification accuracy for each parameter of each hand were presented in (Table 6). Data from left hand of males gave more accurate results regarding correct sex determination compared to right hand. While in females (with the exception of finger breadth) all features from right hand were more accurate in correct sex determination (Table 6).

For both hands; as shown in Table 7, combining features improves the classification accuracy in contrast to using single parameter features alone. The highest classification accuracy of 82% was generated from combining count, square area and density. Combination of the four parameters (by adding finger breadth) did not improve the classification accuracy, as it showed that 82% of males, 70.5% of females and 76.6% of the pooled individuals were correctly classified when the cut value was 0.05.

4. Discussion

Fingerprints of an individual have been used as one of the vital aspects of identification in both civil and criminal cases because of their specialized role in absolute identity.[11] Fingerprints are important to the fields of forensic science and law enforcement. The ridge density of a latent print left at the scene of a crime can be used as an indicator for sex of the perpetrator, helping the fingerprint examiner to direct the criminal investigation toward suspects belonging to the most likely sex, and so minimizing the time and effort spent on each case.[1] Though numerous population-specific researches for fingertip features were done, to best of our knowledge none was done on Egyptians. Thus, the present study aimed to determine the reliability of fingerprint features for accurate sex determination among Egyptians.

Traditionally, fingerprints have been extracted by creating an inked impression of fingertips on paper. Fingerprint images acquired by this way are sensitive to factors such as environmental factors and various skin conditions.[12] As Wang et al.[4] found that many fingerprint images acquired by this way are of poor quality, so we instead used digital camera to capture fingertips' images to determine the sexual dimorphism of fingerprint features within an adult Egyptian population.

Since ridge width varies according to age,[10] so subjects of similar ages (20–30 years) were recruited in this study to ensure that growth had been finished. Ridge count was not analyzed within central core region because of the variability of pattern shapes and the potential problems of recurving ridges being counted more than once within that region. Areas outside of the central core region do not have these confounding problems,[6] making them more suitable for ridge density determinations in this study. Also, all fingerprint pattern types show a similar ridge flow in the selected region.[5]

Results revealed that in Egyptians, the total ridge count showed significant sexual dimorphism (females had higher values than males). This was true for Indians (2, 5 & 9), Chinese and Malaysian.[7] Opposite results were noticed by Mustanski et al.,[13] Van Oel et al.,[14] Ekanem et al.,[15] and Wang et al.[4] where they found that males have more ridge count than females. The contrast may be owing to geographical variation and little number of sampled subjects.

Males tend to have higher square area when compared with females ($p < 0.05$). These results are in agreements with Wang et al.[4] who stated that the finger size feature of Chinese gave the best results of sex discrimination (males larger than females). In

Table 3
Mean, standard deviation and *P*-value for finger breadth (cm) of studied subjects.

Finger breadth	Sex				*t*	*P*-value	Accuracy %		Total accuracy %
	Male		Female						
	Mean	S.D	Mean	S.D			M	F	
Fingers of left hand	10.050	0.798	9.148	1.234	8.517	0.000	72.0%	63.6%	68.1%
Fingers of right hand	10.048	0.857	9.324	1.127	7.064	0.000	80.0%	59.1%	70.2%
Total finger breadth	10.049	0.748	9.248	1.087	8.408	0.000	76.0%	68.2%	72.3%

S.D: Standard deviation.

Table 4
Mean, standard deviation, P-value and accuracy % of ridge density (counts/cm^2) of studied subjects.

Ridge density	Sex				t	P-value	Accuracy %		Total accuracy %
	Male		Female						
	Mean	S.D	Mean	S.D			M	F	
Fingers of left hand	1.302	0.242	1.67	0.403	11.652	0.000	84.0%	70.5%	77.7%
Fingers of right hand	1.343	0.315	1.625	0.391	7.745	0.000	76.0%	52.3%	64.9%
Total ridge density	1.345	0.270	1.663	0.370	9.587	0.000	74.0%	56.8%	66.0%

S.D: Standard deviation.

particular, all of the tested finger size features achieved statistical significance ($P < 0.001$).

The observed statistically significant higher ridge densities found in Egyptian females than in males is the normal consequence to the higher ridge count and the smaller square area detected in females when compared to males. The average body proportions of males are larger than females hence when the same number of ridge is accommodated in a larger surface area and thus, a lower density is observed among males.[16] Higher ridge densities were also found in Spanish Caucasian[1] and Indians.[5] Another explanation was reported by Moore[17] who found a higher value of mean ridge to ridge distance in males than in females, which explain the higher ridge density encountered in females when compared to males. Contrary to our finding, Plato et al.[18] found that the mean ridge density in male is more than female in African Americans and Caucasian Americans. Their different results could be due to ancestral differences or some defects in the counting method.

We found that in males, the mean ridge count for the left hands (20.15 ± 2.15) was lesser than the right hands (20.86 ± 2.34). However in females, the mean ridge count for the left hands (21.43 ± 3.37) was higher than the right hands (21.3 ± 2.43). Green & Young[19] reported that both males and females have higher finger ridge count on their right hand than on their left hand, but Wang et al.[4] reported that Chinese males and females had higher finger ridge count on their left hands than on their right hands. It is not clear whether this inconsistency is caused by the different ridge count measurement method employed or by the difference between the tested populations.

When assessing sex of an individual's fingerprint, ridge density of 1.5 or less for left hand and 1.35 or less for the right hand indicates that the individual is more likely to be of male origin, while higher values indicate that the individual is more likely to be of female origin. Moreover, ridge density in males is greater in the right hand than the left hand, conversely to females. Gutiérrez-Redomero et al.[1] found that ridge density in both sexes of Spanish Caucasian is greater in the left hand. They attributed this to finer ridges than in the right hand.

The sex identification by left hand ridge density is the most single accurate parameter (77.7%), and so it is the most significant parameter. This was also correct for Southern Indians,[5] Caucasian and

Table 5
Results of the multivariate logistic regression variation analysis with the use of sex as a dependent variable.

Variables	B	S.E.	Wald	df	P	Exp
Ridge count (lt)	0.166	0.040	17.623	1	0.000	1.181
Ridge count (rt)	0.077	0.044	3.080	1	0.079	1.080
Ridge count (total)	0.163	0.046	12.218	1	0.000	1.176
Square area (lt)	0.287	0.040	52.247	1	0.000	0.750
Square area (rt)	0.278	0.039	52.088	1	0.000	0.757
Square area (total)	0.351	0.044	62.418	1	0.000	0.704
Ridge density (lt)	3.713	0.421	77.630	1	0.000	40.959
Ridge density (rt)	2.27	0.340	44.660	1	0.000	9.683
Ridge density (total)	3.055	0.391	61.003	1	0.000	21.231
Finger breadth (lt)	0.857	0.119	52.035	1	0.000	0.425
Finger breadth (rt)	0.747	0.119	39.350	1	0.000	0.474
Finger breadth (total)	0.938	0.130	51.768	1	0.000	0.391

SE: standard error, Wald: X2, df: degree of freedom, P: significance, Exp: exponential, rt: right hand, lt: left hand, Total: 10 fingers for both right (rt) and left (lt).

Table 6
Cutoff point and accuracy percentage for sex differentiation for studied parameters from both hands ($N = 752$).

Parameters	Cutoff point	Male accuracy %	Female accuracy %
Ridge count (lt)	Female > 21.2 ≥ Male	70%	55%
Ridge count (rt)	Female > 21.0 ≥ Male	60%	60%
Square area (lt)	Male ≥ 15.1 > Female	68%	72.7%
Square area (rt)	Male ≥ 16.1 > Female	66%	75%
Ridge density (lt)	Female > 1.5 ≥ Male	84%	70.5%
Ridge density (rt)	Female > 1.35 ≥ Male	64%	80%
Finger breadth (lt)	Male ≥ 9.38 > Female	78%	63.6
Finger breadth (rt)	Male ≥ 9.54 > Female	68%	61.4

lt: left hand, rt: right hand.

Table 7
Classification accuracy by using multiple features.

Parameter	Accuracy		
	Male accuracy	Female accuracy	Total accuracy
Ridge count	74.0%	50.0%	62.8%
Square area	76.0%	65.9%	71.3%
Ridge density	74.0%	56.8%	66.0%
Finger breadth	76.0%	68.2%	72.3%
Count & square area	80.0%	72.7%	76.6%
Count & density	74.0%	61.4%	68.1%
Count & finger breadth	82.0%	68.2%	75.5%
Square area & density	80.0%	68.2%	74.5%
Square area & finger breadth	76.0%	65.9%	71.3%
Density & finger breadth	80.0%	70.5%	75.5%
Count, square area & density	82.0%	82.0%	82%
Count, square area & finger breadth	82.0%	70.5%	76.6%
Count, density & finger breadth	82.0%	70.5%	76.6%
Square area, density & finger breadth	80.0%	70.5%	75.5%
Density, count & finger breadth	82.0%	68.2%	75.5%
Density, square area & finger breadth	80.0%	70.5%	75.5%
Count, square area, density & finger breadth	82.0%	70.5%	76.6%

African Americans.[6] While in Chinese, finger size in both sexes was more significant than ridge count and ridge density because males have more ridge counts but smaller ridge densities than females.[4]

It is worthy to note that Teke et al.[20] mentioned that accuracy less than 70% is considered as relatively low-accuracy rate. We found that the greatest accuracy (82%) resulted from combining ridge count, square area and density. Addition of the finger breadth did not improve the effective classification accuracy. This can be explained by the poor performance of the finger breadth feature for sex determination. Wang et al.[4] found that the best classification result of 86% accuracy is obtained by using ridge count and finger size features together in Chinese.

5. Conclusion

* The present results demonstrate the effectiveness of the proposed fingertip features for sex determination.
* Women tend to have a statistically significant greater ridge density than men.
* Ridge density of 1.5 or less and 1.35 or less for the left and right hands respectively is more likely to be of male origin, and more than the previous values is most likely to be of female origin.
* The best classification accuracy of 82% was generated from combining count, area and density.

6. Recommendations

- Fingertip features looks promising for sex determination in Egyptians.
- Using combined fingertip features (ridge count, square area and ridge density) are recommended for improved accuracy.

Ethical approval
None declared.

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None declared.

Conflict of interest
None declared.

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